Toward a Better Understanding of Ocean-Wave-Typhoon Interactions in the Western Pacific Ocean

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LONG-TERM GOALS

This project investigates the interplay among typhoon-strength winds, ocean surface waves and upper-ocean circulation during and after typhoon passages over the western Pacific Ocean and around the island of Taiwan.

OBJECTIVES

We will use three numerical models and calibrate them against continuous measurements of ocean currents, temperature, wave heights and turbulence intensities from several open ocean moorings in the western Pacific. Through these calibrations, we will learn how to better represent winds, ocean currents and waves under typhoon-strength wind conditions in the western Pacific Ocean.

APPROACH

For the atmosphere, we will use the Navy's operational West Pacific atmospheric model (COAMPS) and JPL wind to drive ocean waves and upper ocean circulation. For ocean waves, we use SWAN (Booji et al.,1999; Ris et al., 1999) to generate them and calibrate simulated results against observed wave heights from moorings. For the ocean circulation, we invoke the Naval Research Laboratory's Ocean Nowcast/Forecast System (ONFS, Ko et al., 2008) to simulate upper-ocean response. The resolutions of these models are sufficiently high. Through calibration and analysis of the three models and observations, we intend to identify crucial oceanic and wave processes that regulate typhoon's strength and path.

Key individuals participating in this work include Shenn-Yu Chao as the lead PI and Dong-Shan Ko of NRL, who will maintain ONFS and provide wind products. Ya-Ting Chang, visiting from Institute of Oceanography, National Taiwan University, will serve as the liaison between our modeling components and Taiwanese observation components. Her efforts along this line of investigation will constitute the bulk of her Ph.D. dissertation.

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WORK COMPLETED

We have completed the construction and implementation of SWAN model for the western Pacific under typhoon-strength wind conditions. As a test case, we used SWAN to simulate surface waves during and after the passage of typhoon Krosa-2007, and calibrated the SWAN results against four coastal wave stations along the east coast of Taiwan. Further, the Ocean Nowcast/Forecast System with much refined resolution for the western Pacific has been transferred from NRL to UMCES successfully and poised to simulate the upper ocean circulation under typhoon-strength winds in the region.

RESULTS

Figure 1, derived from COAMPS, shows two snapshots of ocean surface winds during the Krosa passage. Initially from southeast of Taiwan, the Krosa moved northwestward from 10/4/9GMT to 10/5/15GMT with little intensification. It subsequently landed on northeast of Taiwan and continued its track toward China.

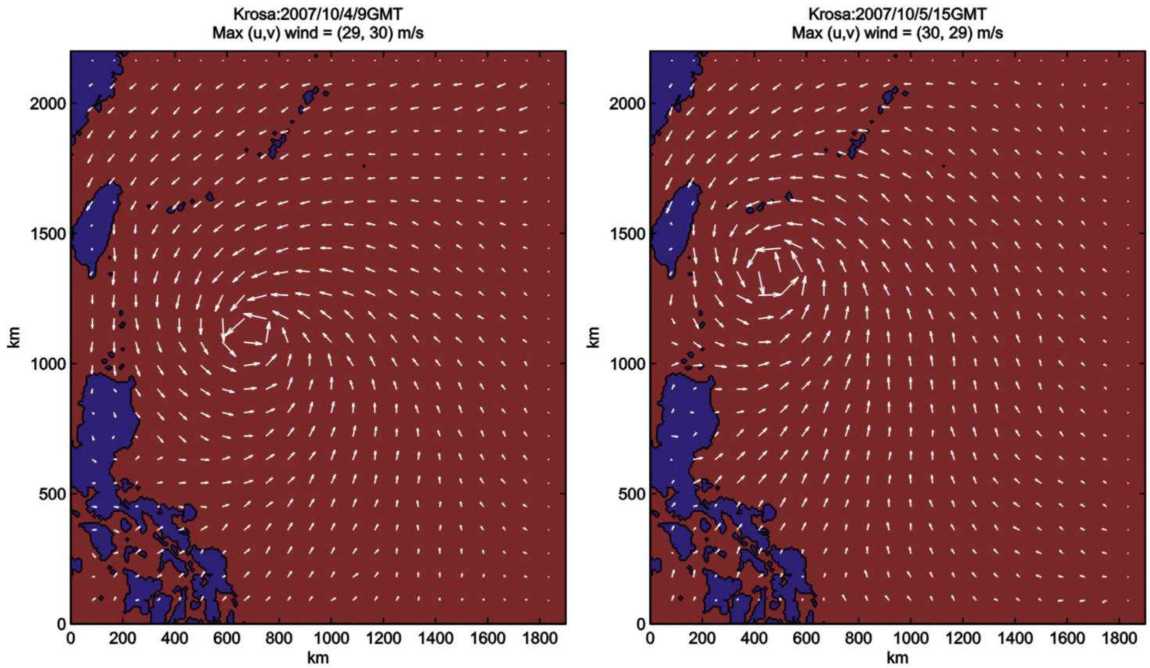

Figure 1 Surface winds under Krosa at 10/4/09GMT (left) and 10/5/15GMT (right).

Figure 2, derived from ONFS, shows contemporaneous upper ocean current under Krosa. Under the typhoon center, cyclonic eddy development lagged somewhat behind the Krosa arrival. Backward (eastward) radiating currents are also evident as part of the inertial oscillations in the wake of Krosa.

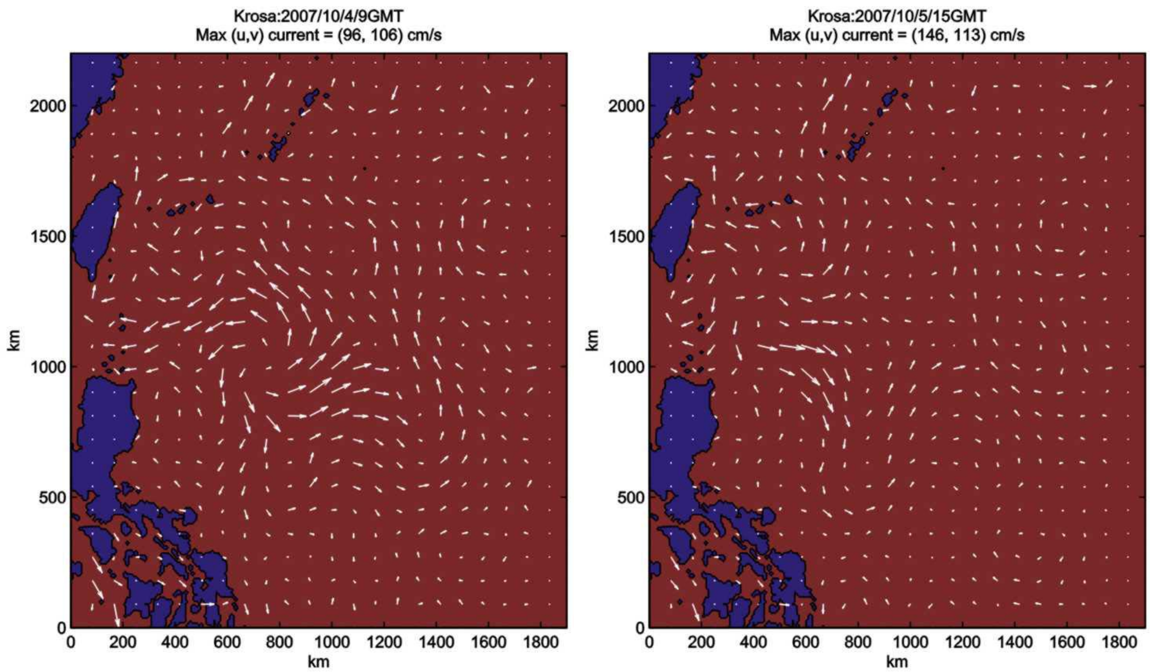

Figure 2 Upper ocean currents under Krosa at 10/4/09GMT (left) and 10/5/15GMT (right).

In wave modeling, the traditional practice is to use winds to drive waves without due regards to upper ocean currents. It is therefore not *a priori* clear that ocean currents can alter the wave fields markedly under typhoon-strength winds. Our results indicate that the upper ocean currents did not play a significant role when Krosa was over the open ocean, but became important after the Krosa moved to the Kuroshio and its eddy region. Figure 3 shows the difference in the wave field induced by upper ocean currents at 10/15/18GMT. At this time Krosa was approaching the Kuroshio and its offshore eddies (top left panel). This is the time upper ocean currents exerted the maximum influence on the wave fields. The upper ocean currents enhanced the wave heights up to 3 m east of the Luzon Strait (top right panel). The mean wave period decreased by up to 2 seconds under Krosa (bottom left panel), and the average wavelength increased by up to 30 m east of the Luzon Strait (bottom right panel). Thereafter the upper ocean current effect diminished in time.

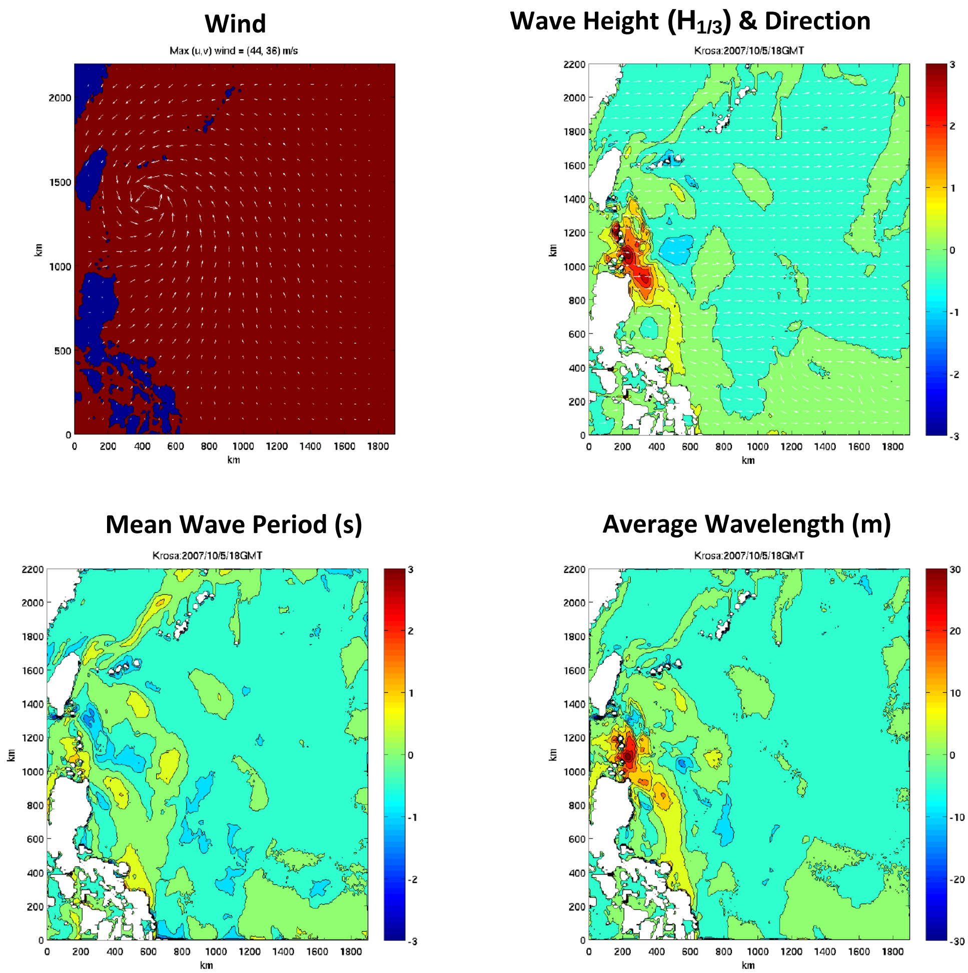

Figure 3 Krosa wind (top left) and difference induced by ocean current in wave height (m) and direction (top right), mean wave period (s) and average wavelength (m) at 10/15/18GMT.

IMPACT/APPLICATIONS

We have used typhoon Krosa as a test case to simulate ocean waves in the western Pacific Ocean. Contrary to open ocean settings, we have demonstrated the necessity to include the effect of upper ocean currents over the Kuroshio and eddy region. Otherwise the simulated wave height is too mild east of the Luzon Strait, the wave period is too long under Krosa and the wavelength is too short east of Luzon Strait. To a certain extent, the wave field alters the ocean mixed layer, which in turn regulates the amount of upper ocean heat content released to the atmosphere. Thus, a more realistic wave field may ultimately produce better typhoon strength and track forecasts. In this light, it seems necessary to include the upper ocean currents in order to better forecast typhoons after they come into contact with the Kuroshio and its adjacent eddies. Further, a more realistic wave field may also improve upper ocean circulation and lead to better regional ocean models. Our investigation along this line is still ongoing.

RELATED PROJECTS

Typhoons over the western Pacific Ocean ultimately impact the South China Sea and East China Sea. The altered circulations and heat content in both Seas will, in turn, feed back to influence the next few typhoons. In this connection, we are also coorporating with Taiwanese ITOP investigators (T. Y. Tang and H. J. Lee) to look into circulation and thermodynamics in seas around Taiwan.

REFERENCES

Booij, N., Ris, R.C., and L.H. Holthuijsen (1999) A third-generation wave model for coastal regions. Part I: Model description and validation, Journal of Geophysical Research, 104, 7649-7666.

Ko, D.-S., P. J. Martin, C. D. Rowley, and R. H. Preller (2008) A real-time coastal ocean prediction experiment for MREA04. Journal of Marine Systems, 69, 17-28.

Ris, R.C., N. Booij and L.H. Holthuijsen (1999): A third-generation wave model for coastal regions. Part II: Verification, Journal of Geophysical Research, 104, 7667-7682.

PUBLICATIONS

Chang, Y.-T., W.-L. Hsu, J.-H. Tai, T. Y. Tang, M.-H. Chang, and S.-Y. Chao (2009) The cold deep inflow in the South China Sea, J. Oceanography. [submitted, refereed]

Lee, H.-J., S. Jan, S.-Y. Chao, G.-C. Gong, and K.-K. Liu (2009) Tidal effects on Changjiang plume dispersal in the East China Sea, Ocean Dynamics. [submitted, refereed]